CORRESPONDENCE

Comments on "Structure of a Cold Front Near the Center of an Extratropical Depression"

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In the November 1964 issue of the *Monthly Weather Review*, Schwerdtfeger and Strommen [1] used hourly rawinsonde observations made at Bedford, Mass. in April 1960 for a detailed analysis of the structure of a cold front. They attempted to show that the important temperature changes at upper levels occurred several hours following the passage of the front at the earth's surface and that the cooling extended nearly vertically throughout most of the troposphere. The structure of this so-called "main front" was inferred primarily from information given by a sounding made at 2112 GMT on April 5, 1960. It is the purpose of this note to question the reliability of this sounding and, in turn, the reality of the frontal structure described by Schwerdtfeger and Strommen.

The rawinsonde observation released at Bedford at 2112 GMT, April 5, 1960 showed a cooling from the previous hour of over 4° C. through most of the layer from 1000 to 350 mb. and some cooling up to about 160 mb. There had been very little cooling at the surface following the frontal passage about 10 hr. earlier, and the surface pressure continued to fall following the frontal passage. The hourly observations from Boston show that the pressure started rising after 1900 GMT and rose at the rate of 1.0 to 2.7 mb. $hr.^{-1}$ during the period from 2000 to 0100 GMT, with a rise of 1.7 mb. in the hour preceding the questionable sounding. The hourly rainfall observations in eastern Massachusetts show widespread, but generally light, rain ending between 2300 and 2400 GMT with the hourly amount at no station exceeding 0.07 in. in the 2000–2200 GMT period. The surface observations, therefore, suggest that nothing unusual was happening during the hour preceding, or following, the sounding which indicated the very marked cooling throughout most of the troposphere.

The 2112 GMT sounding is very difficult to accept because of its implications in regard to the vertical extent of the pressure-height minimum associated with the cooling. The largest height falls in the curves presented by Schwerdtfeger and Strommen were at the highest level included in their diagram. This was at 200 mb., or some 80 mb. above the tropopause. It can be seen from hydrostatic reasoning that in order to limit the height falls to the lower stratosphere it would be necessary to postulate rather marked warming above the 200-mb. level in association with the so-called "main front." A study by Kantor [2] showed that there were no marked changes in the character or height of the tropopause or in the thermal structure in the 200–100-mb. layer during the hour preceding and following the questionable sounding.

Another difficulty in accepting the 2112 GMT sounding is that the following observation (2200 GMT) indicated warming throughout much of the troposphere, especially in the 400- to 200-mb. layer. This warming after the frontal passage would suggest that the temperature changes could not have been due to synoptic-scale advection since a general cooling persisted for several hours following the 2200 GMT sounding. The warming shown between the 2112 and 2200 GMT soundings resulted in rather large height rises during a period when the heights at all upper troposphere levels were generally falling. It would seem that the only possible means of explaining the low temperature at 2112 and the higher temperatures at 2200 would be to postulate ascending motion in the so-called frontal zone and descending motion to its rear. However, the surface pressure changes and hourly rainfall amounts mentioned previously offer no evidence for any marked changes in the vertical motion pattern during the 2000–2200 GMT period.

Schwerdtfeger and Strommen suggest that the relatively strong winds at upper tropospheric levels at 2112 GMT can be associated with the thermal gradients in the nearly vertical frontal zone. An association of this type would imply that temperatures were still falling at 2112 GMT and, therefore, that the warming following the frontal passage was actually even more pronounced than indicated by their time section based on the hourly soundings.

The evidence presented in this note suggests that the marked cooling shown by the 2112 GMT sounding can hardly be accepted when viewed in relation to the observed weather and motion patterns. If this sounding is discarded and 2-hourly temperature changes are used,

it is possible to arrive at a completely different picture of the thermal structure in the upper troposphere than that deduced by Schwerdtfeger and Strommen. Instead of a nearly vertical frontal zone, it would have been possible to draw a sloping zone more in line with the classical frontal model.

There are undoubtedly many frontal zones in the middle and upper troposphere which bear little resemblance to the Norwegian model and the writer agrees with Schwerdtfeger and Strommen that more realistic frontal models are needed. It is felt, however, that their model, in which the cold air advances in a nearly vertical wall, is unrealistic for the case presented. This model would have required compensating warming at levels above 100 mb. and it would presumably have required strong vertical motion patterns at a time when the weather distribution indicated relatively uniform, light precipitation.

REFERENCES

1. W. Schwerdtfeger and N. D. Strommen, "Structure of a Cold Front Near the Center of an Extratropical Depression," *Monthly Weather Review*, vol. 92, No. 11, Nov. 1964, pp. 523–531.
2. A. J. Kantor, "Tropopause Definition and Hourly Fluctuations," *Environmental Research Papers*, No. 41, Air Force Cambridge Research Laboratories, Office of Aerospace Research, L. G. Hanscom Field, Mass., 1964, 23 pp.

[*Received February 21, 1966*]

REPLY

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In his interesting comments Dr. Jordan suggests that the results of one individual ascent appear to be doubtful, and that our conclusions (Schwerdtfeger and Strommen [1]) would be different if we had discarded this sounding.

The extenso publication of the data used (Court and Salmela [2]) can serve as evidence of the commendable care with which the Bedford series of 161 soundings has been evaluated. Neither Court and Salmela, nor A. J. Kantor [3] who discusses shortcomings of the radiosondes and cites two errors he found or suspects, expresses doubts about the sounding to which Dr. Jordan objects. A comparison with the preceding and following hourly ascents indicates little temperature change in the stratosphere, between 100 and 20 mb. Of course, when at the same time there is little surface pressure change and a strong cooling of the troposphere, the pressure-height changes must extend into the upper stratosphere. This indeed may be remarkable, but certainly is not impossible.

The pronounced change of thickness and the appearance of a slightly unstable lapse rate in unsaturated air between 600 and 540 mb., together with an absolutely stable structure of the atmosphere between the surface and 700 mb. were accompanied only by a temporary change from light to moderate rain at Bedford, by the occurrence of showers at Boston. See the hourly observations of these two stations plotted at the bottom of figure 1 in [1]. The fact that nothing more spectacular happened concurrently with the thickness change cannot, in our opinion, be construed as an argument against the reliability of the results of a sounding. On the other hand, the observed wind and its change with time in the middle and upper troposphere, as illustrated in figure 11 in [1] bear a closer relationship to the pressure-height changes computed *with* the questioned sounding than without.

Naturally, a radiosonde which is not recovered cannot be recalibrated, and therefore its reliability always remains, to a certain degree, a matter of conjecture. The more important question really is whether our general interpretation of the case would be "completely different" if the 2112 GMT sounding were non-existent, or if it had indicated 1° or 2° higher temperatures throughout the troposphere and correspondingly a smoother change of the affected thickness values. This suggestion must be emphatically declined. The beauty of the observational material used for our study really is that the soundings are so numerous, that is, one every hour. A fine, comprehensive graphical representation of all these soundings has been given by Kantor [3] in his figures 1 through 7. A rapid change of temperature in most of the troposphere already is put in evidence by the 1900 and the 2000 GMT soundings (see also our fig. 1 [1]). If we disregard the 2112 ascent as Dr. Jordan would prefer to do, we would have for the 400–900-mb. layer a thickness change of 159 g.p.m./3 hr.; the temperature at the 500-mb. level would change from −14.2° to −25.2° C. in the same time interval, 1900 to 2200 GMT. There still would be no indication of the cooling in the lower layers (say, 900 to 700 mb.) occurring prior to the cooling in the upper layers (say, 600 to 300 mb.) of the troposphere, and no evidence whatsoever for a wedge-like configuration of the colder air mass.